Statement of Work – Conductivity, Temperature, and Flow Vector Analysis of the Red Hill Groundwater Monitoring Network

PROBLEM DESCRIPTION

The Navy's Red Hill Bulk Fuel Storage Facility (Facility) is located above two of Oahu's most important drinking water aquifers. The Facility was constructed over 70 years ago consisting of 20 – 12.5-million-gallon underground storage tanks (USTs) the bottoms of which are separated from the basal groundwater by 100 to 200 feet (ft) of permeable basalt. Three major municipal pumping centers are located within a mile and a half of the USTs including the Halawa Shaft, Hawaii's largest public drinking water source (refer to Figure 1 and Section 1 of Attachment 1). In January 2014, the Navy reported a 27,000-gallon release from the Facility (Attachment 1, Section 4.5). As a result of that release the Navy and the regulatory agencies (U.S. Environmental Protection Agency and the Hawaii Dept. of Health [DOH]) entered into an Administrative Order on Consent (AOC). One of the provisions on the AOC Statement of Work (SOW) is that Navy will develop groundwater flow and transport models to better understand groundwater flow direction, velocity, and contaminant transport in the vicinity of the Facility. Complex geology and very small differences in groundwater elevations within the Red Hill Groundwater Monitoring Network (RHGMNW) complicate the use of groundwater gradients to assess groundwater flow directions and velocities, or to validate the groundwater flow model results (refer to Attachment 2). Validation of a groundwater flow model is further complicated by the diverse ion and isotopic chemistries within the RHGMNW that do not show any cohesive transport paths.

The primary purpose of this survey is to assist DOH in determining groundwater flow trajectories at a site where neither the relative groundwater elevations or groundwater chemistry show trends that can constrain the groundwater flow paths beneath the Facility. ~~which of two contrasting conceptual models of groundwater flow direction and velocity best reflects actual groundwater flow trajectories in the vicinity of the Facility. The Navy's conceptual model is of rapid southwesterly groundwater flow from recharge areas in the highlands toward coastal and nearshore spring discharge points (Attachment 1, Section 6.5). The groundwater geochemistry shows diverse compositions over relatively short distances suggesting that the mixing that would be expected to accompany rapid groundwater movement is not occurring. Further, w~~While the water table is very flat (refer to Figures 6-8 through 6-12 of Attachment 1), there does appear to be a regional gradient to the northwest (refer to Attachment 2, pages 10-12). For the purposes of assessing the risk that the Facility poses to public drinking water sources it is critical ~~that the divergence in the conceptual models of groundwater flow be narrowed~~that the groundwater flow trajectories be understood to enable planning for contamination remediation and response actions to any future releases.

Commented [D1]: Regional?

Commented [WR2R1]: yes

Currently the ~~Fully understanding groundwater flow paths in the vicinity of the Facility and nearby production wells is critical to validating the~~ Navy's groundwater flow model is the AOC approach ~~and ultimately understanding~~to assess the risk that the Facility poses to groundwater and drinking water. However, the very flat groundwater gradient and ambiguous chemistry indicators make validating the groundwater flow model difficult. The most comprehensive validation of the proposed Conceptual Site Model (CSM) and Numerical Flow Model (NFM) will be through the execution of a properly designed tracer test. It DOH's approach to use the a Colloidal Borescope flow vector survey to reduce ~~However, design of such a test requires some knowledge of groundwater flow rates and directions; currently, there is a strong divergence between the flow vectors and flow rates proposed by the CSM and NFM~~

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~~(Attachment 1 Section 6.5) and those inferred from physical and chemical parameters measured in the monitoring well network (Attachment 2, pages 10-12). In order to resolve this~~ groundwater flow trajectory ~~disparity~~ uncertainty for risk assessment and aid in follow-on ~~and allow refinement of the expected trajectories~~ tracer test design~~of tracers~~,. These the refined groundwater flow trajectories and identification of flow zones within the wells will also be used to inform multi-level sampling.

We propose the execution of an initial borehole monitoring campaign using a colloidal borescope, or equivalent, to determine approximate horizontal rates and directions of water flow within the top ~~several~~ 10 to 20 feet~~meters~~ of the water table underlying the Navy's Red Hill Bulk Fuel Storage Facility (Facility). A Colloidal Borescope was successfully used to measure groundwater flow rates and vectors in the monitoring well network for the Waimanalo Gulch Landfill (Attachment 3). The results of this survey indicated that this, or a similar technology, could provide insight into the groundwater flow vectors and rates through the RHGMNW at the Facility and enable us to design a groundwater tracer test that will better define the regional groundwater flow patterns.

Technical Specifications

- Evaluate the saturated water column in the Facility monitoring wells for evidence of preferential flow zones
- Define horizontal flow vectors in 2-inch and 4-inch monitoring wells where horizontal velocities may range from 0.1 to 60 ft/d;
- Perform these surveys in wells where the total depth varies from 100 to 500 ft
- Since flow rates in the borehole differ from those in the surrounding geologic media perform the necessary transformations to provide the indicated aquifer flow velocities;
- Produce time series plots and rose diagrams of flow vector showing the magnitude, direction and frequency of measured flow vectors;
- Produce a technical report describing the methods and findings; ~~and~~
- Give a presentation on the methods and findings to a meeting of the Red Hill AOC Stakeholders (a remote presentation is acceptable); and
- Ensure all downhole instruments and materials are properly decontaminated between wells using industry standard decontamination procedures, containerize investigative derived waste (IDW) and arrange for disposal.
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Commented [D3]: It might be interesting, if not useful, to look at a 24 hour monitoring interval with and/or without pumping being done in RHS or Halawa Shaft.

General Considerations – The Facility is a Department of Defense Controlled Industrial Area with strict security protocols. DOH will work with the contractor and the Navy to provide access to the Facility. This usually involves up to half a day getting the necessary passes. All personnel that enter the Facility must have U.S. citizenship and be able to demonstrate this with proper documentation.

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As with all such investigations personnel safety is a prime concern. The contractor shall follow of State and Federal safety requirements that will include personal protection equipment that at a minimum will include hard hat, steel toed safety shoes, eye and hearing protection, and safety vests.

Wells RHMW02, RHMW03, and RHMW05 area located in the Facility lower access tunnel near the bottom of the USTs. This will require coordinating with Facility personnel to put the equipment on the small gauge utility train at the lower entrance to the lower access tunnel. The train will then take personnel and equipment to the wells to be surveyed. Assume this will add 1 to 2 hours to the workday.

The lower access tunnel is very secure, and equipment can be left unmolested overnight so the additional time would only apply to mobilizing into the tunnel and demobilizing from the tunnel. Access to RHMW04, RHMW09, and RHMW10 will require coordination with Facility security since there are additional locked gates on the roads to these wells. These gates are in addition to Facility main gate.

~~STATEMENT OF WORK~~REQUESTED TASKS

Task 1 – Develop a Workplan and Quality Assurance Plan for a conductivity/temperature/depth (CTD) profiling and borehole flow vector survey of selected wells in the RHGWMNW. These plans shall describe the methods, the data collected, quality assurance measures to ensure data integrity, and the data and formats that the results will be presented in. Coordinate with DOH and UH personnel on selecting the wells to be profiled.

Task 2 –CTD Profile: Inflections and abnormalities in the vertical temperature and conductivity profile of a well can indicate different flow zones within a well bore. Conduct a CTD profile on wells to be surveyed immediately prior to the deployment of the Borescope into the well during both the pumping and non-pumping condition borehole flow vector surveys. These data shall be used to refine the vertical placement of the Borescope for flow vector measurements.

~~All downhole instruments and materials will be properly decontaminated between wells using industry standard decontamination procedures, containerize investigative derived waste (IDW) and arrange for disposal.~~

DOH may do a preliminary CTD survey to screen for flow zones prior to the contractor coming on site. If this is done, data will be made available to the contractor as soon after data acquisition as possible.

Task 3 – Perform groundwater flow vector survey on at least six wells each for Red Hill Shaft pumping and Red Hill Shaft off conditions. Working with DOH and UH personnel, select at least six wells in the RHGWMNW to measure the horizontal groundwater flow vectors during "normal" Red Hill Shaft operations of cyclic pumping. Repeat the tests during a sustained period where the Red Hill Shaft is not pumping. It will take approximately three (3) days after the Red Hill Shaft shutdown for the groundwater elevations to equilibrate sufficiently to conduct the second set of borehole flow vector measurements. Table 1 lists the construction details for the wells in the RHGWMNW that are suitable for borehole flow vector analysis. Refer to Figure 1 and Figures ~~x-x~~1-1 of Attachment 1 for a site map and well locations. Wells RHMW02, RHMW03, and RHMW04 are priority wells for flow vector analysis. The remaining three or more wells will be selected based on mutual agreement between the contractor and DOH.

For each set of ~~RHFVM~~ borehole flow vector measurements (i.e. Red Hill Shaft pumping and Red Hill Shaft not pumping), the flow in the well will be measured at a minimum of two depths in each well. Each flow vector survey test will run for at least 40 minutes and until in the professional opinion of the operator a sufficient amount of data has been collected for reliable flow vector calculation. At least four sets of measurements, with each at least 40 minutes long, will be done at a minimum of two depths in each well. Thus at least eight 40-minute tests will be done at each well for each pumping condition. Due to RHMW04's strategic location between the Facility and the Halawa Shaft, at least one 24 hour test will be done at this well for each pumping condition. Select depths for testing to include any points where the CTD profile anomalies or inflections indicate a flow zone might be present, where vertical

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Commented [D5]: Do you want to have the borescope in one or two wells during the transition period from pumping to non pumping to document the aquifer response during that period?

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Commented [WR7]: Selected 40 minutes so a survey for a well could be completed within an 8 hour work day.

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positioning of the colloidal borescope indicates a stable flow field (refer to Attachment 4) or ~~—If the CTD profiling fails to identify a flow zone, a set of flow vector measurements will be done~~ at depths of 33 and 67 percent of the saturated water column in each well if a flow zone is not indicated by the CTD profile or by vertical displacement of the colloidal borescope.

DOH suggests that two teams each with a CTD profiler and colloidal borescope be deployed to conduct the surveys. This gives the study the distinct advantage of measurement of the flow field at two locations simultaneously.

~~**All downhole instruments and materials will be properly decontaminated between wells using industry standard decontamination procedures, containerize investigative derived waste (IDW) and arrange for disposal**~~

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Task ~~5~~ 4 – Produce a technical report describing the methods, quality assurance, results, and conclusions of this investigation. The contractor will present the results to a Red Hill AOC Stakeholder Group meeting. These meetings have the capability for remote ~~presentationspresentations~~presentations, so the contractor need not be physically present at the meeting.

Data Quality Objectives

1. Measure the rates and directions of groundwater flow in individual monitoring wells under ambient and pumping conditions using a colloidal or dye borescope.
2. Document the pumping conditions at Red Hill and Halawa shafts contemporaneously with the borescope testing.
3. Compare measurements above with the Navy CSM and GWFMs to assess the consistency and reliability of those interpretations and calculations.
4. Use the data and comparisons above to assess the viability and potentially plan a full scale groundwater tracer test to further assess broader-scale groundwater behavior.

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The contractor will provide:

- Borescope(s), cable reel with 550 ft of cable, and computer interface
- Computer
- Water level indicator
- Power supply for remote sites (Note: need for clean power)
- PPE and safety equipment
- Decontamination supplies and containers for IDW
- Need a catchall statement
- CTD loggers and readout units,

Commented [D8]: Will we be able to operate with two long cable instruments? Need to confirm that they will be available or whether we will need to go with one long cable and one short cable set (and coordinate the measurement locations accordingly).

DOH will provide:

- In cooperation with the University of Hawaii provide at least one person per team to assist with the borehole flow vector survey including equipment movement and setup, decontamination,
- Will coordinate with the Navy on such things as site access, and management of the Red Hill Shaft pump operation timing

Attachments:

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1. Navy Facilities Engineering Command. 2019. Conceptual Site Model, Investigation and Remediation of Releases and Groundwter Protection and Evaluation, Red Hill Bulk Fuel Storage Facility – Joint Base Pearl Harbor-Hickam. Prepared by AECOM Technical Services, Inc. June 30, 2019 (electronic link will be emailed)

2. Hawaii Department of Health. 2019. Hawaii Department of Health Evaluation of Groundwater Flow Paths in the Moanalua, Red Hill, and Halawa Regions; Revision 2. July 2019

3. Geosyntec Consultants. 2012. Updated Evaluation of the Groundwater Monitoring System – Waimanalo Gulch Sanitary Landfill – Kapolei, Oahu, Hawaii. Prepared for the Hawaii Department of Health. May 2012

4. Zhan, H., Lui, B., and Lan, X. 2019. A new method for measuring the flow velocity and direction of groundwater. 4th International Conference on Energy Equipment Science and Engineering, IOP Conf. Series: Eath and Environmental Science 242 (2019). https://www.researchgate.net/publication/332099062_A_new_method_for_measuring_the_flow_velocity_and_direction_of_groundwater

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Table X. Well Construction Details of the Red Hill Wells

Well Name	Well ID	Casing Material	Top of Casing Elevation	Well Total Depth (ft)	Screen Length	Elevation Bottom of Screen	Average Water Elev.	Average Saturated Interval	Comments
			(ft msl)		(ft)	(ft msl)	(ft msl)	(ft)	Located inside the lower access tunnel. Power available
RHMW02	NA	2” Sch 80 PVC	104.60	99	15.0	6.0	18.7	13	Located inside the lower access tunnel. Power available
RHMW03	NA	2” Sch 80 PVC	120.90	117	15.0	4.0	18.6	15	Located inside the lower access tunnel. Power available
RHMW04	NA	4” Sch 80 PVC	312.11	305	15.0	7.6	18.6	11	Exterior well, no power available; 24 hour flow vector survey desireable
RHMW05	NA	2” Sch 80 PVC	101.31	93	15.0	8.7	18.8	10	Exterior well, no power available
RHMW06	3-2253-004	4” Sch 80 PVC	259.09	263	30.0	-4.2	18.8	23	Exterior well, no power available
RHWM08	3-2253-007	4” Sch 80 PVC	310.43	312	30.0	-1.1	18.7	20	Exterior well, power available may be available
RHMW09	3-2253-008	4” Sch 80 PVC	395.37	397	30.0	-2.0	18.2	20	Exterior well, no power available
RHMW10	3-2253-009	4” Sch 80 PVC	495.59	497	30.0	-2.0	18.5	21	Exterior well, no power available
OWDF-MW1	NA	4” Sch 80 PVC	138.14	145	11.1	-5.4	18.8	11	Exterior well, power available may be available

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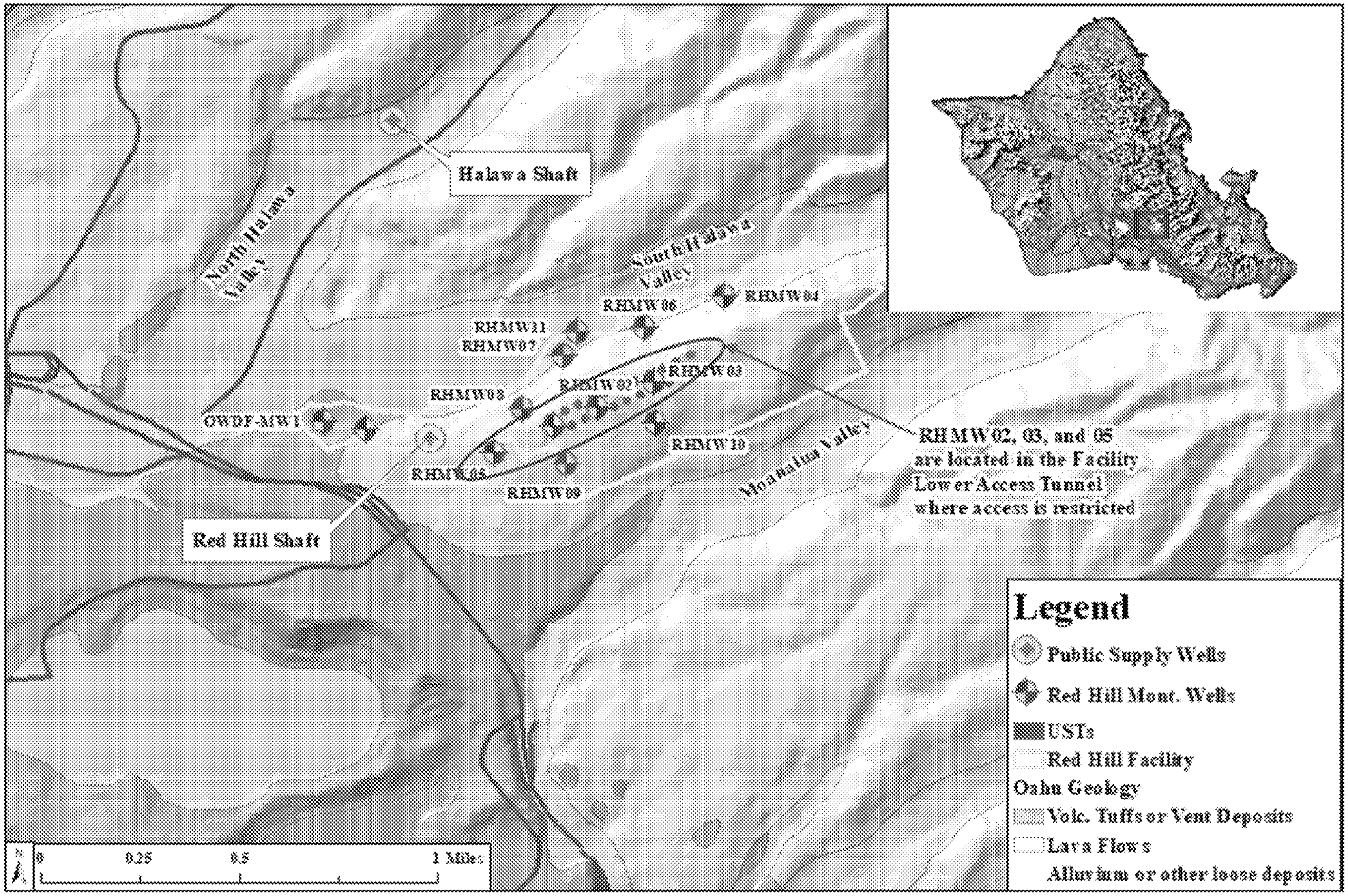

Figure 1. The locations of the wells listed in Table 1, the Facility boundaries, Public Supply Well potentially impacted by a release from the Facility, and the area geology are shown above.

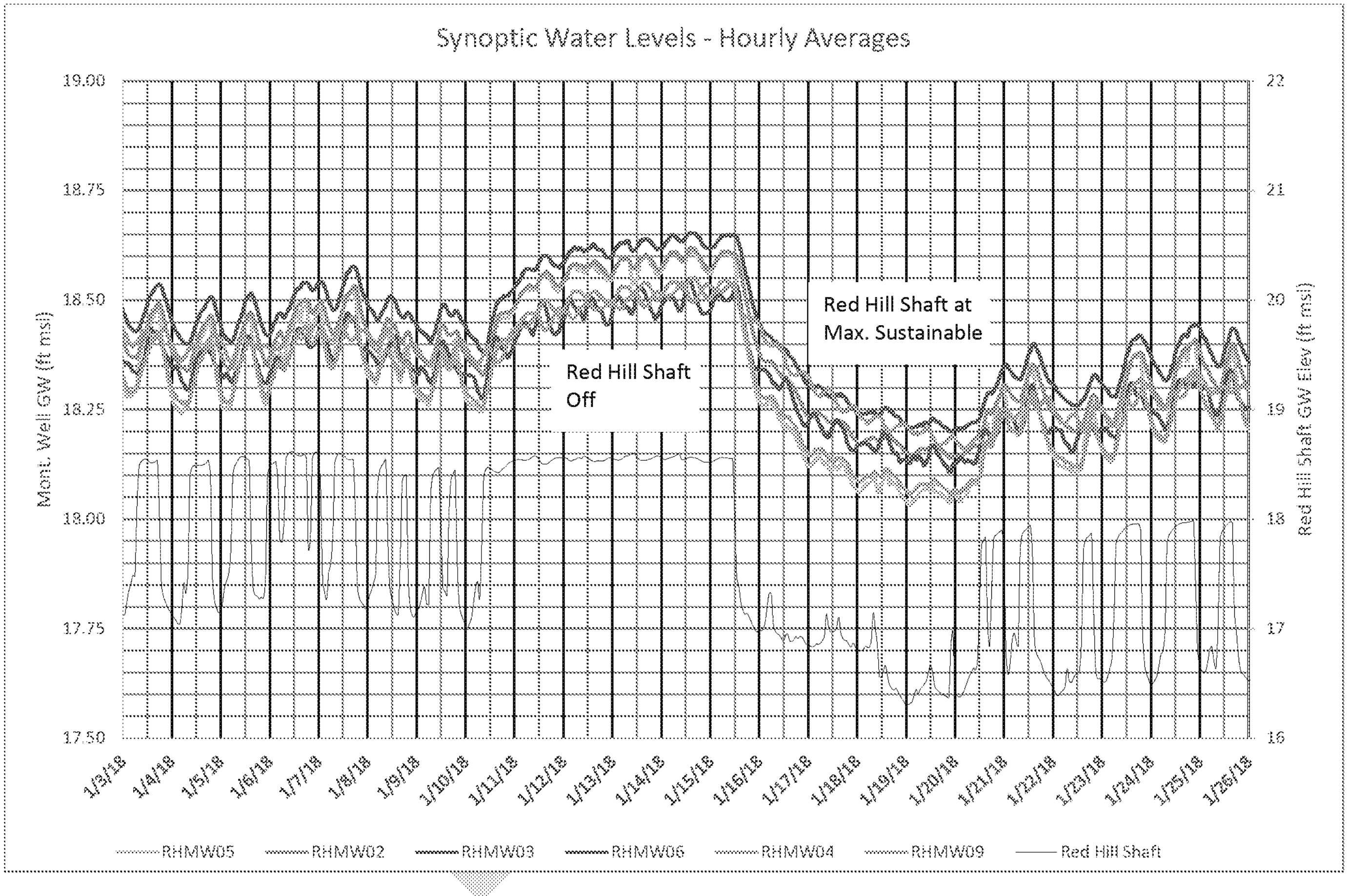

Figure 2. Response of the water levels in the Red Hill monitoring wells to changes in pumping stresses at the Red Hill Shaft

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